# High Resolution Digital Elevation Models of Mars from MOC Narrow Angle Stereoimages

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ISPRS-ET Workshop
18 October 2001

# Introduction

- These slides were presented to the Mars Exploration Rovers (MER) Landing Site Workshop, 10/18/01
- Emphasis is on results of slope analysis for candidate MER landing sites
- More detailed description of methodology and slope results for Mars Pathfinder site are presented in abstract, online at http://wwwflag.wr.usgs.gov/USGSFlag/Space/Isprs/index.htm

  (Click “Meetings” and follow the links to 2001 workshop abstracts)

Thanks to E. Howington-Kraus, T. Hare, B. Archinal!

# Preview of Conclusions

Of sites studied NONE meet MER engineering requirement of 99th %ile slope ≤ 15° at 5 m

Preferred Estimates

| Site | Slope |
|---|---|
| Melas | 38.2° |
| Gusev | 32.0° |
| Isidis | 27.0° |
| Eos | 37.6° |
| MPF site | 20.4° |

- This is not a "squeaker". Sites do not meet criterion relaxed to permit the Mars Pathfinder Ares Tiu site.

# Overview of Methodology

- Rely on MOC-NA images
  - 2x2 summation, ~3 m resolution
- Stereoanalysis
  - Horizontal resolution ≥3 pixels (10 m)
  - Vertical precision ~2m w/high confidence
- Photoclinometry
  - Horizontal resolution ≥1 pixel
  - Model-dependent; calibrate amplitude to stereo to improve confidence
  - Subject to artifacts due to albedo variations
- Usually sample slightly different areas

# Challenge #1

## Develop Analysis Tools

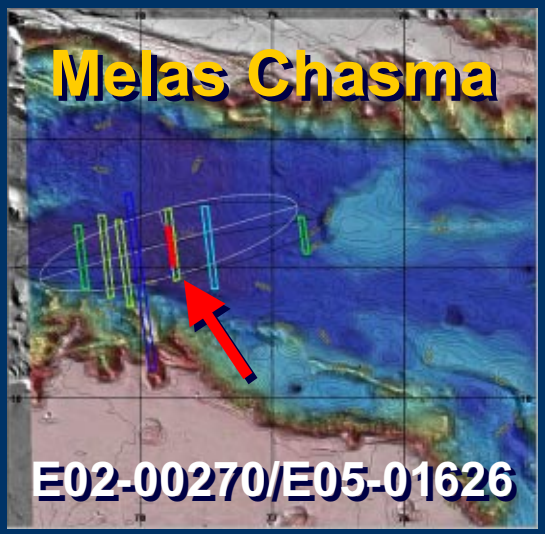
- We use commercial photogrammetric workstation (LH Systems SOCET SET) combined with ISIS
- Includes “generic pushbroom scanner” sensor model that can describe MOC
  - Adjustment capability limited
- Wrote software to ingest/setup images
- Also use Kirk’s 2D photoclinometry and slope analysis software

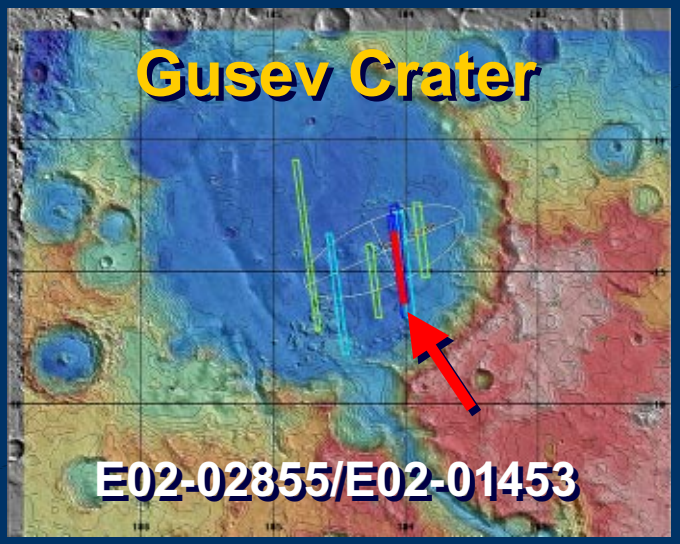
# Challenge #2

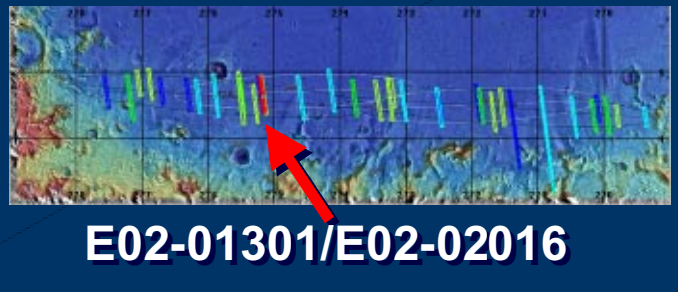
## Identify MOC-NA Stereopairs

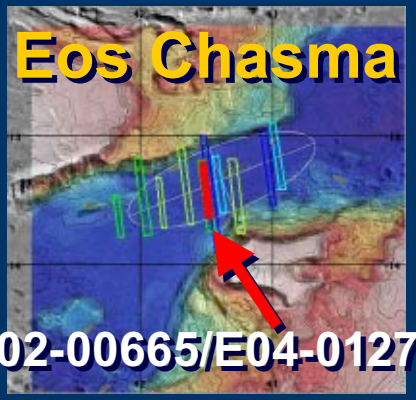
- Manual search
  - MSSS press releases -> past LS's
  - MER LS website -> some images for MER
- Automated search
  - Sift MOC cumulative index
    - Look for overlaps (allow for pointing errors)
    - Require compatible illumination
    - Validate image quality & overlap by inspection
  - Found good pairs for 4 sites
  - Also Gale crater but overlap ≤500 m wide

# MER Landing Site Stereopairs



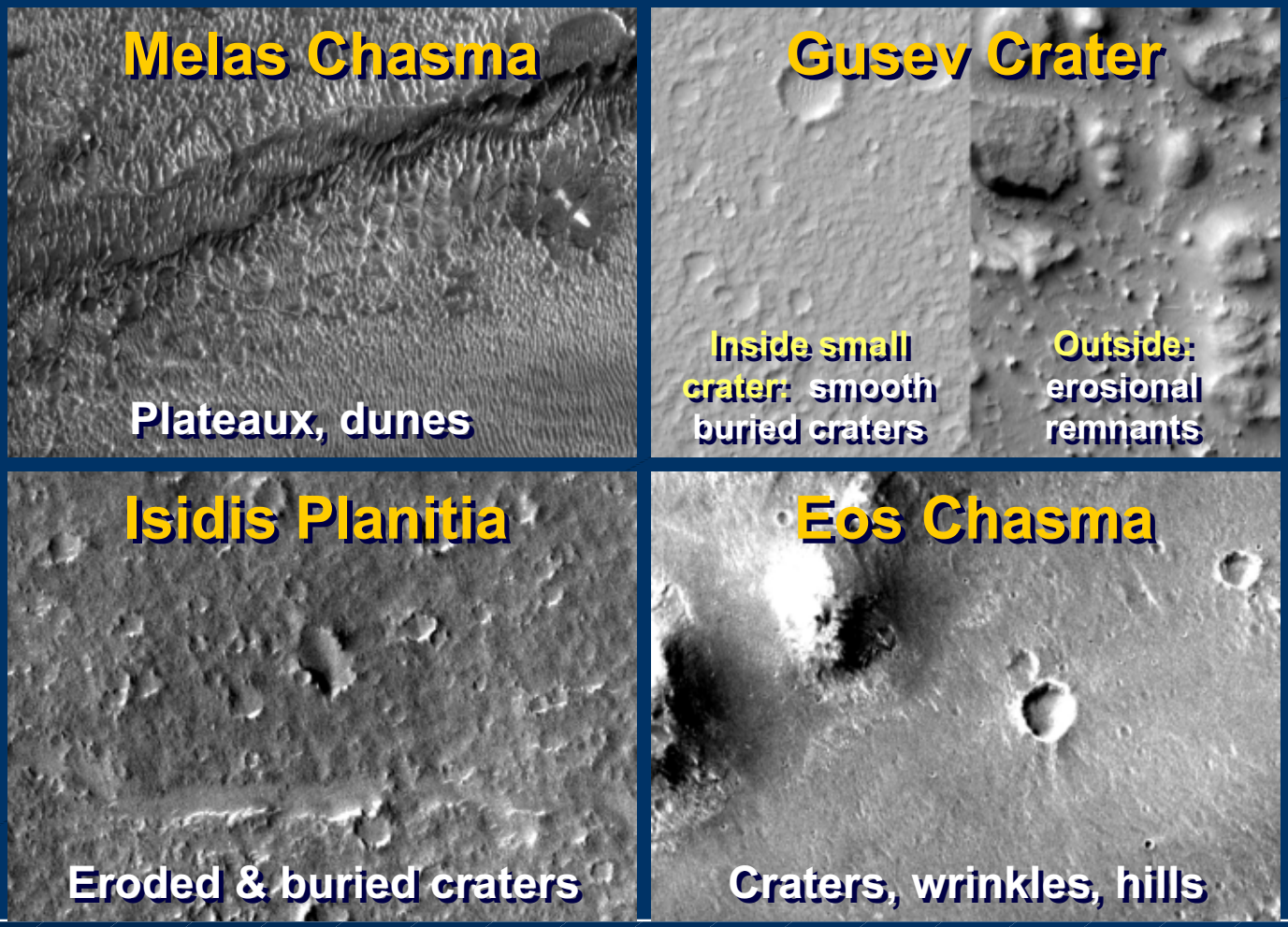



# Characterization of the Sites

AKA “Why Randy is not a geologist…”



# Challenge #3

## Control Images

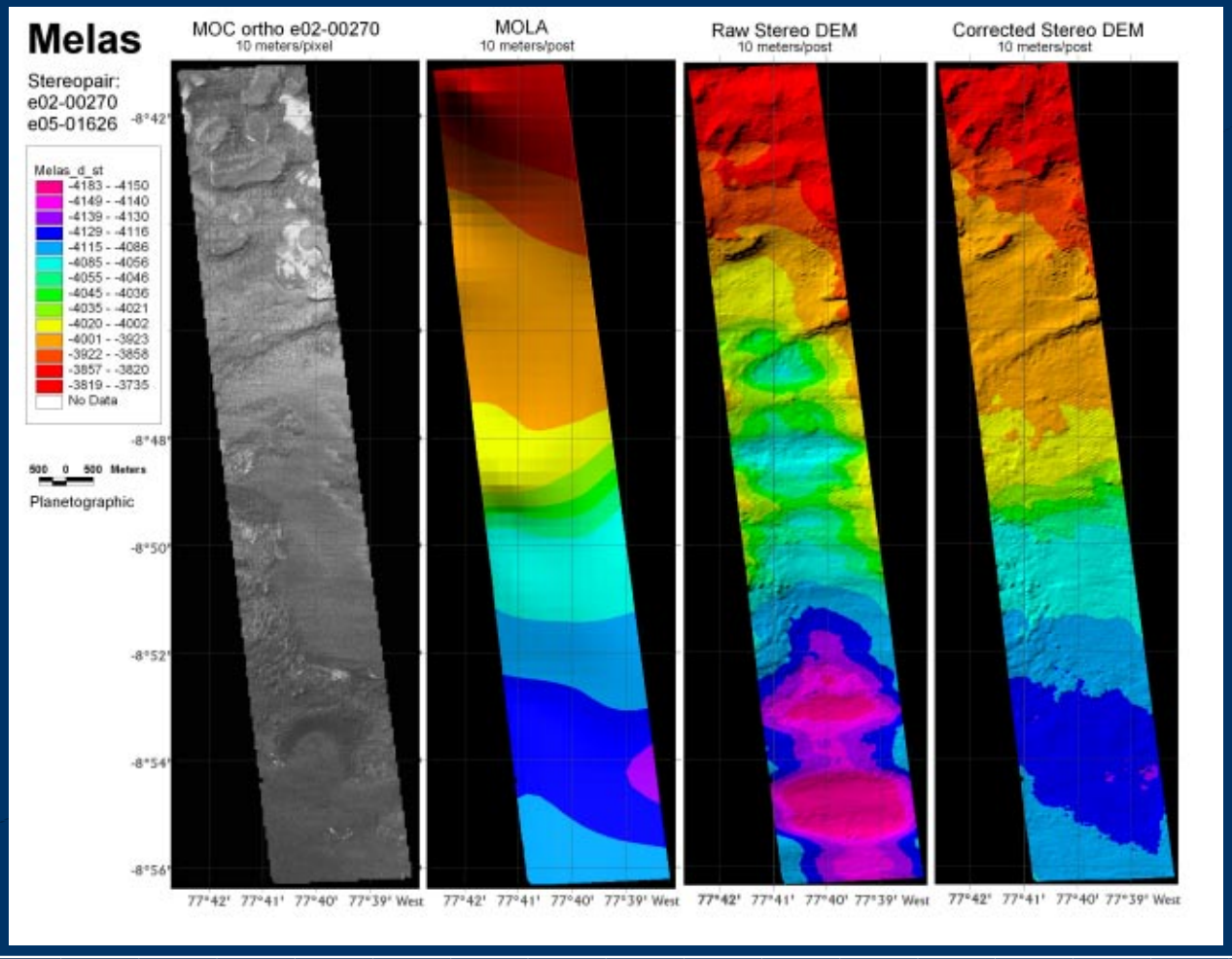
- Do least-squares adjustment in SOCET
  - Position/velocity offsets in 3 axes
  - Rotation offset/vel/accn in 3 angles
  - Does NOT handle high-frequency “wiggles”—have proposed to develop adjustment s/w that does
- Constrain tiepoints to elevations interpolated from MOLA (USGS 500m grid for each site)
- Did not attempt absolute horizontal control
  - Would require ties to MOLA via intermediate resolution images
  - Not necessary for roughnness analysis
  - Horizontal positions OK to few x 100 m

# Challenge #4

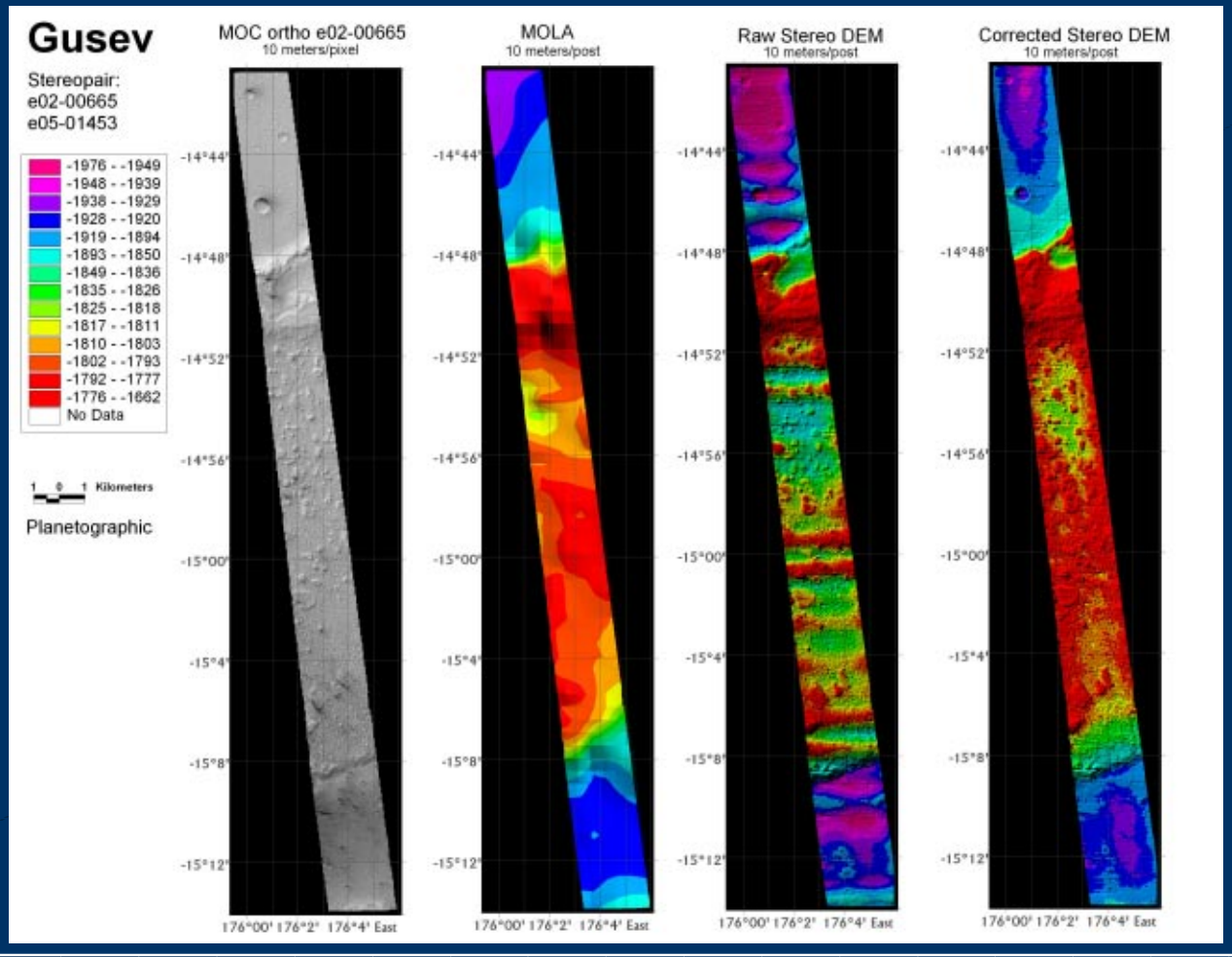
## Collect and edit DEM Data

- Collect by automatching,edit w/stereo display
- High-frequency s/c pointing oscillations cause *serious* problems for DEM collection & use
  - Periods 0.25–1 s, amplitudes ≤50 uRad
    - Also seen in SPICE CK but aliased to ≥4 s
  - Cross-track oscillations mimic stereo parallax, cause DEM to undulate (10s of m amplitude)
    - Digitally filter DEMs to suppress undulations
  - Along-track oscillations cause matching image lines to wander in and out of alignment.
    - Stereo matcher “loses lock” and fails
    - Collect in sections, adjusting for offset, then edit together

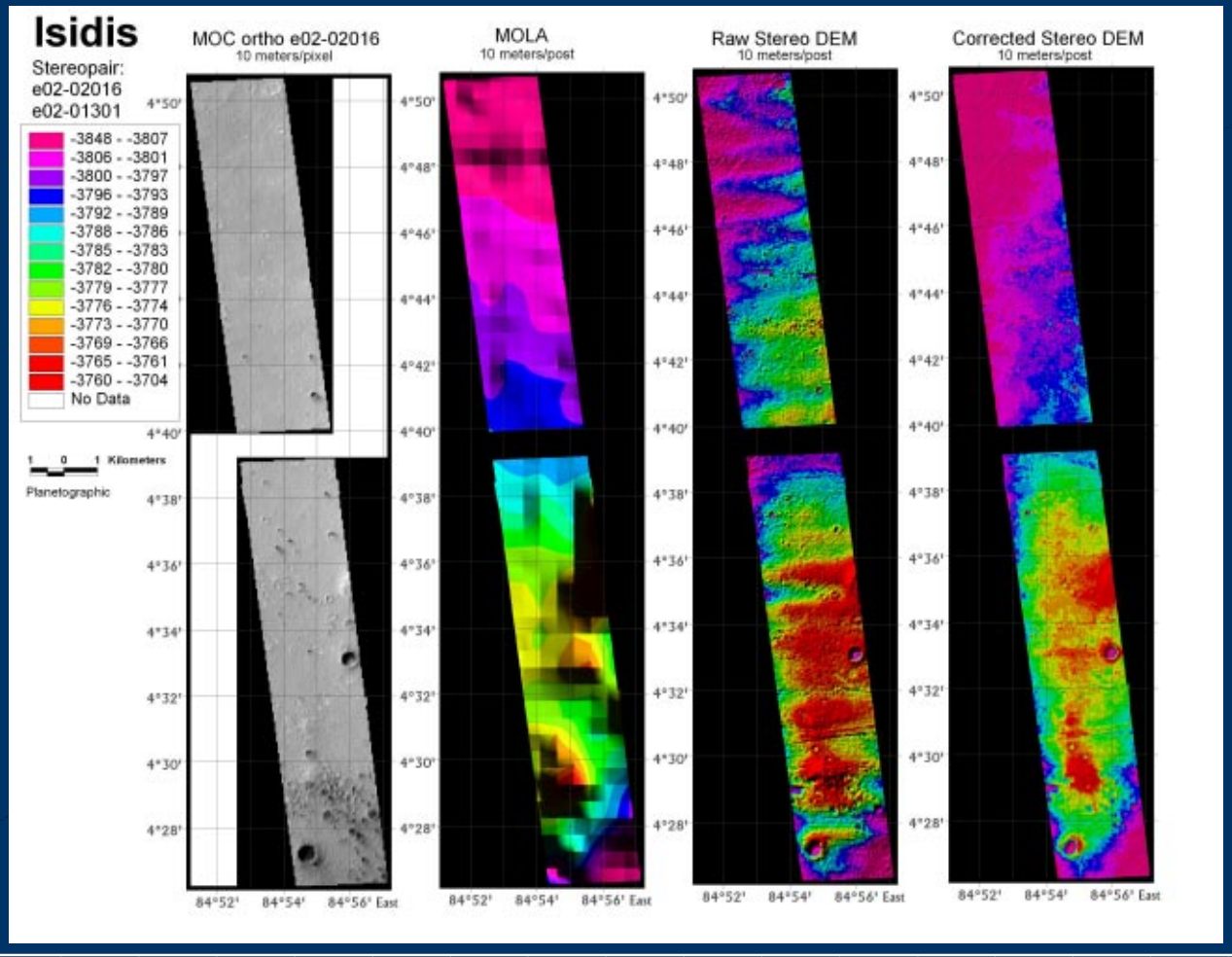
# Melas: E02-00270/E05-01626



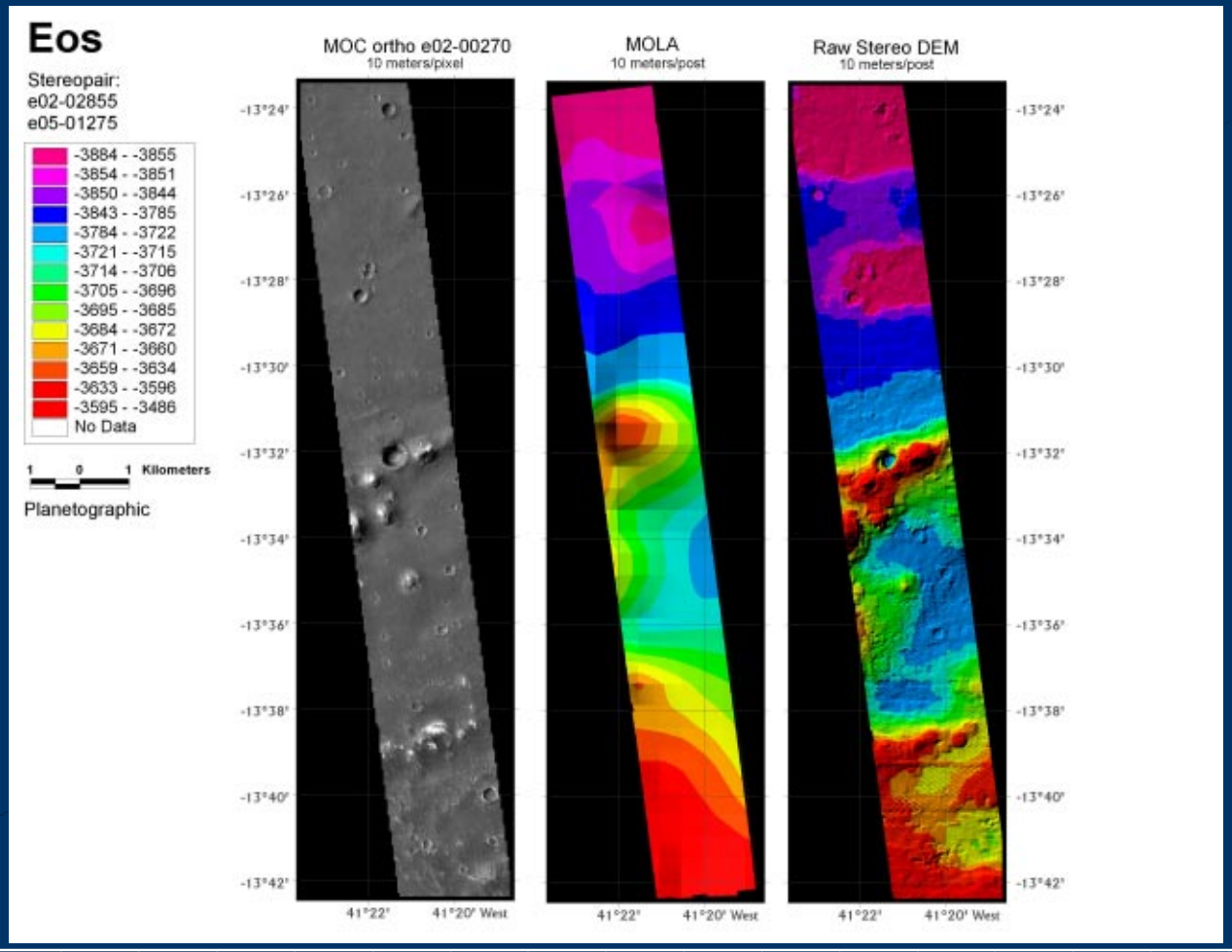
# Gusev: E02-00665/E02-01453



# Isidis: E02-01301/E02-02016



# Eos: E02-02855/E04-01275

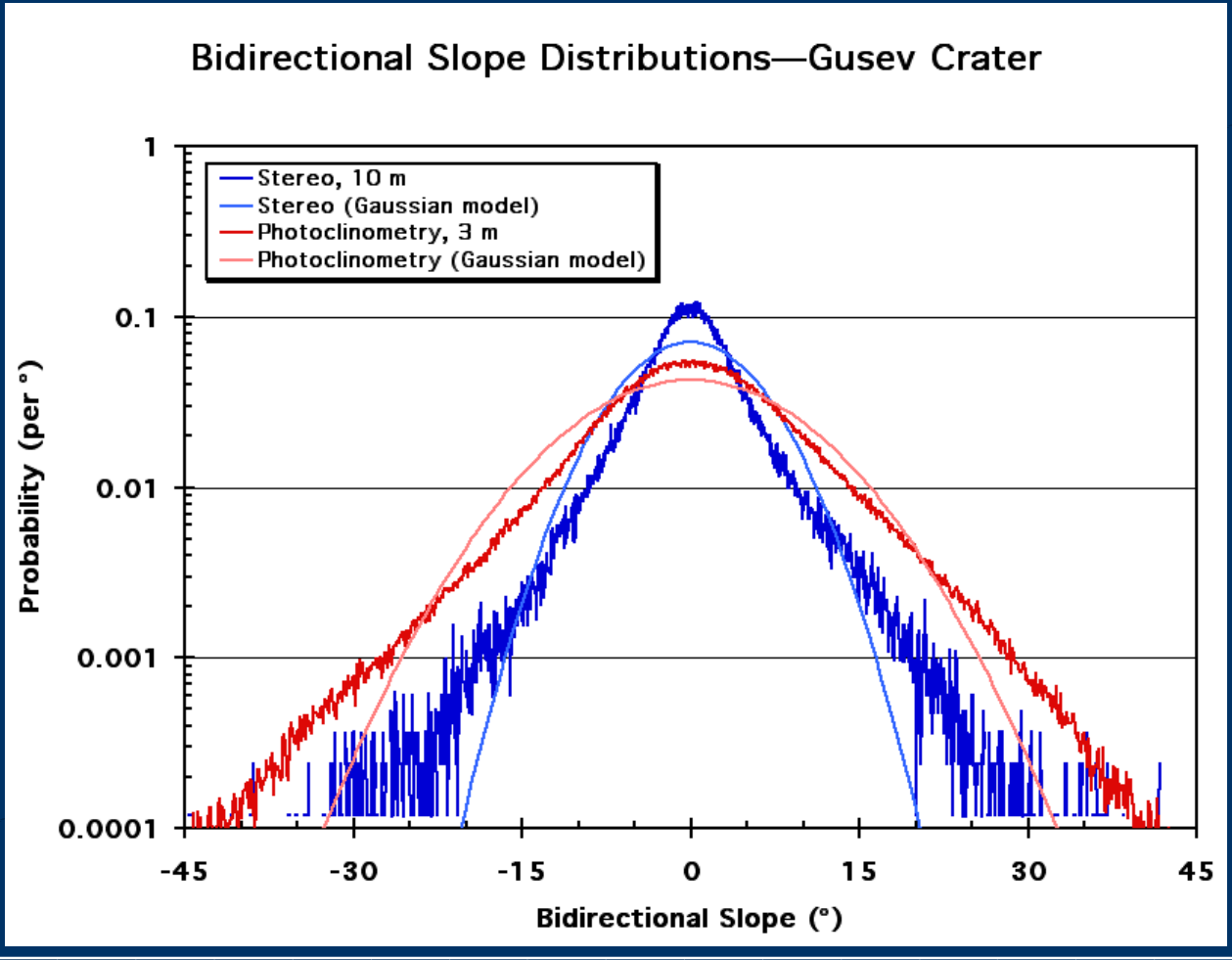


# Challenge #5

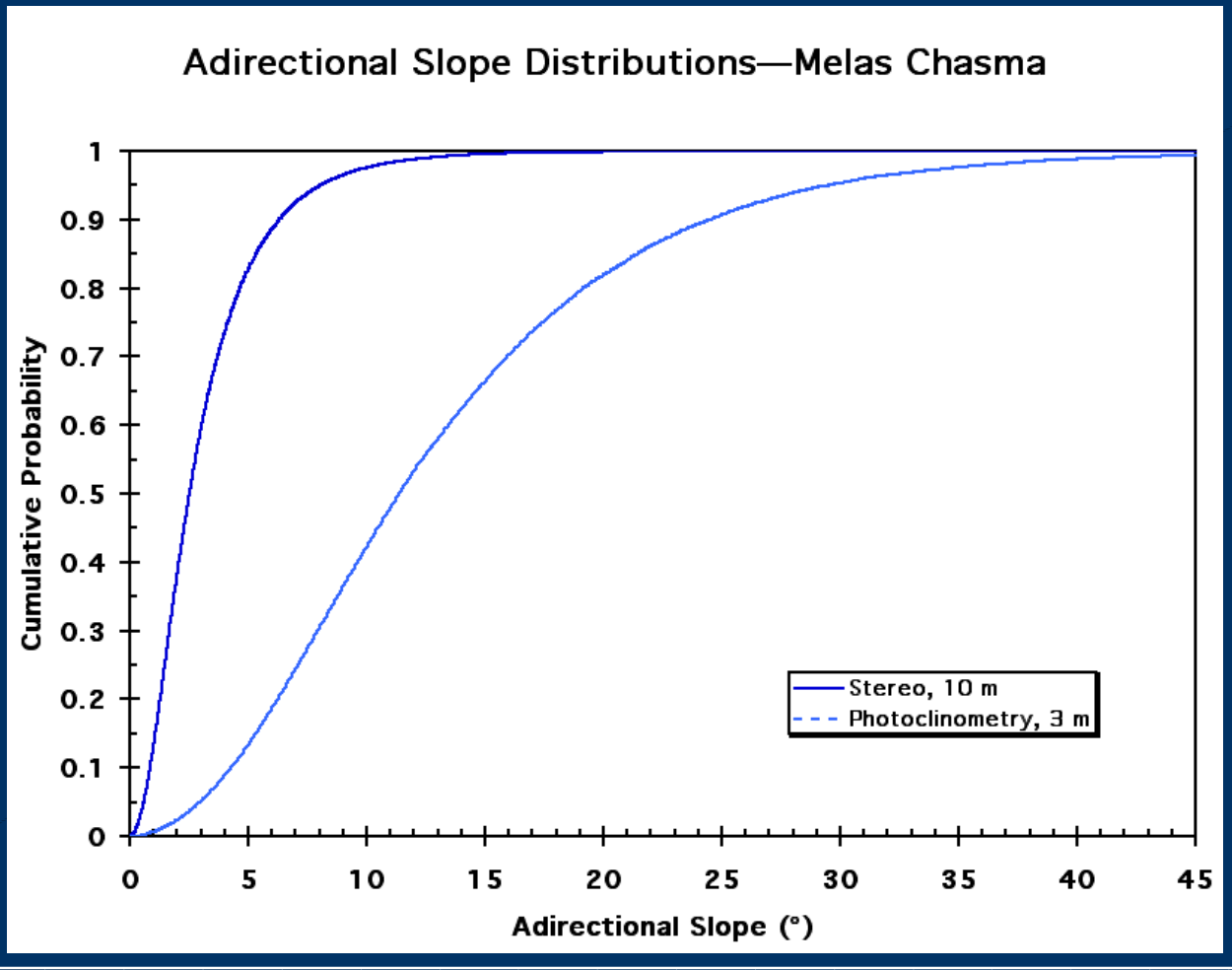
## Characterize Surface Roughness

- Direct calculation of slopes
  - Adirectional (gradient) or bidirectional (e.g., E-W)
  - Gives shape of entire slope distribution
    - Distributions are long-tailed: extreme slopes are more common than RMS slope might suggest
  - Limited to single horizontal baseline at a time
- Fourier transform techniques
  - Limited to bidirectional slope
  - Gives RMS slope only, not distribution
  - Quickly gives variation with baseline
    - Are slope-producing features adequately resolved?

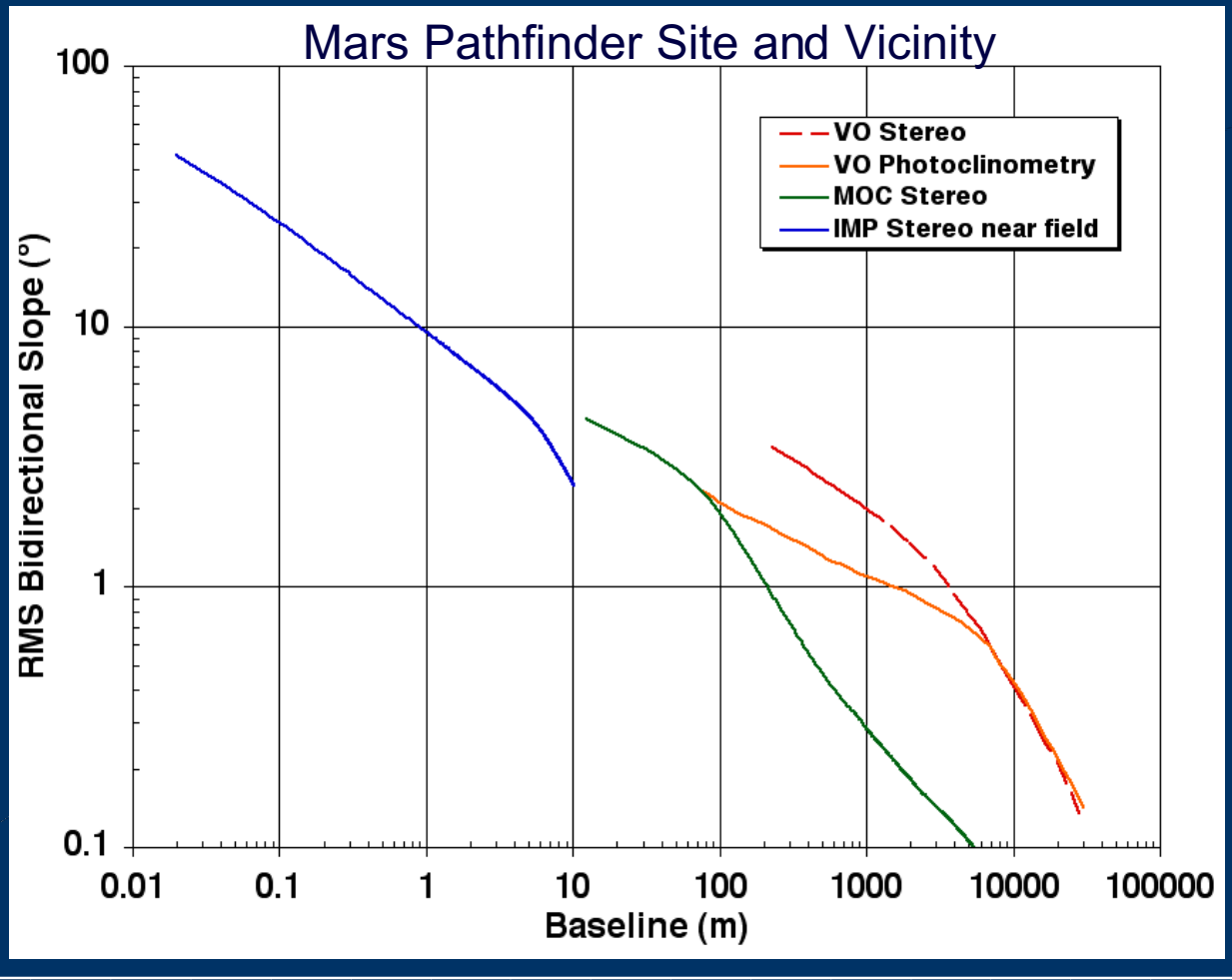
# Example: Bidirectional Slope Distributions



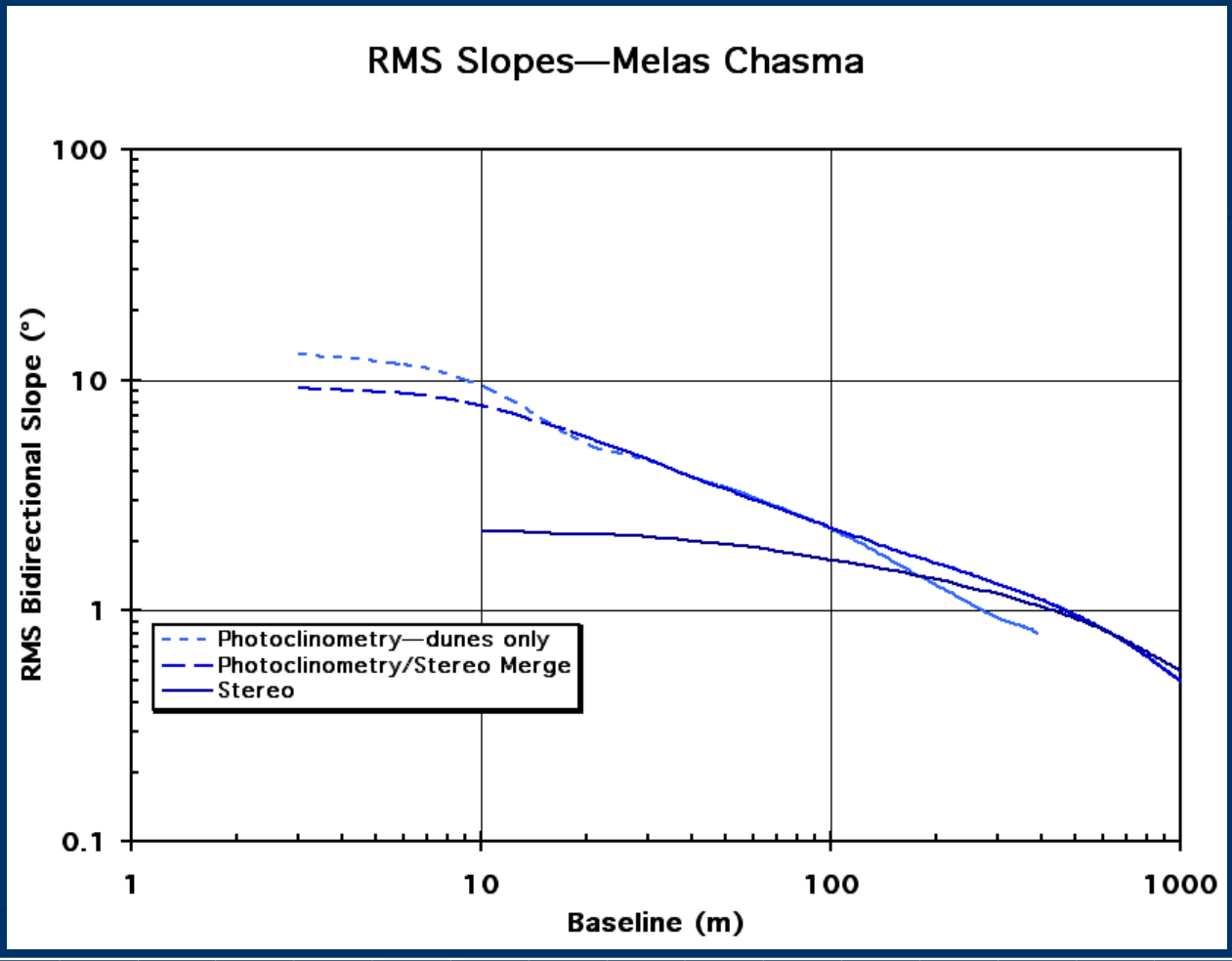
# Example: Adirectional Slope Distributions



# Example: Slope vs. Baseline



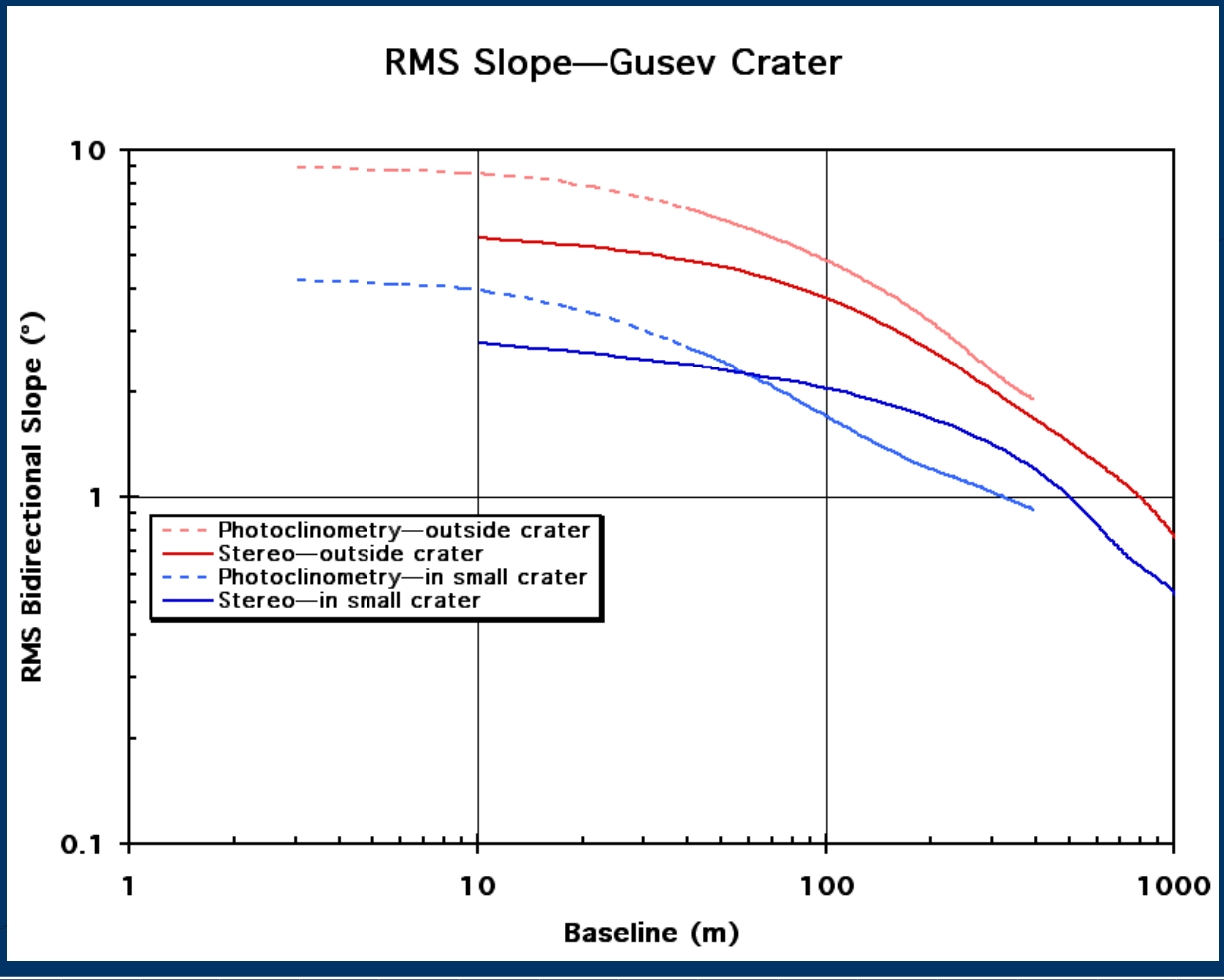
# Melas: Slope vs. Baseline




Stereo fails to resolve dunes

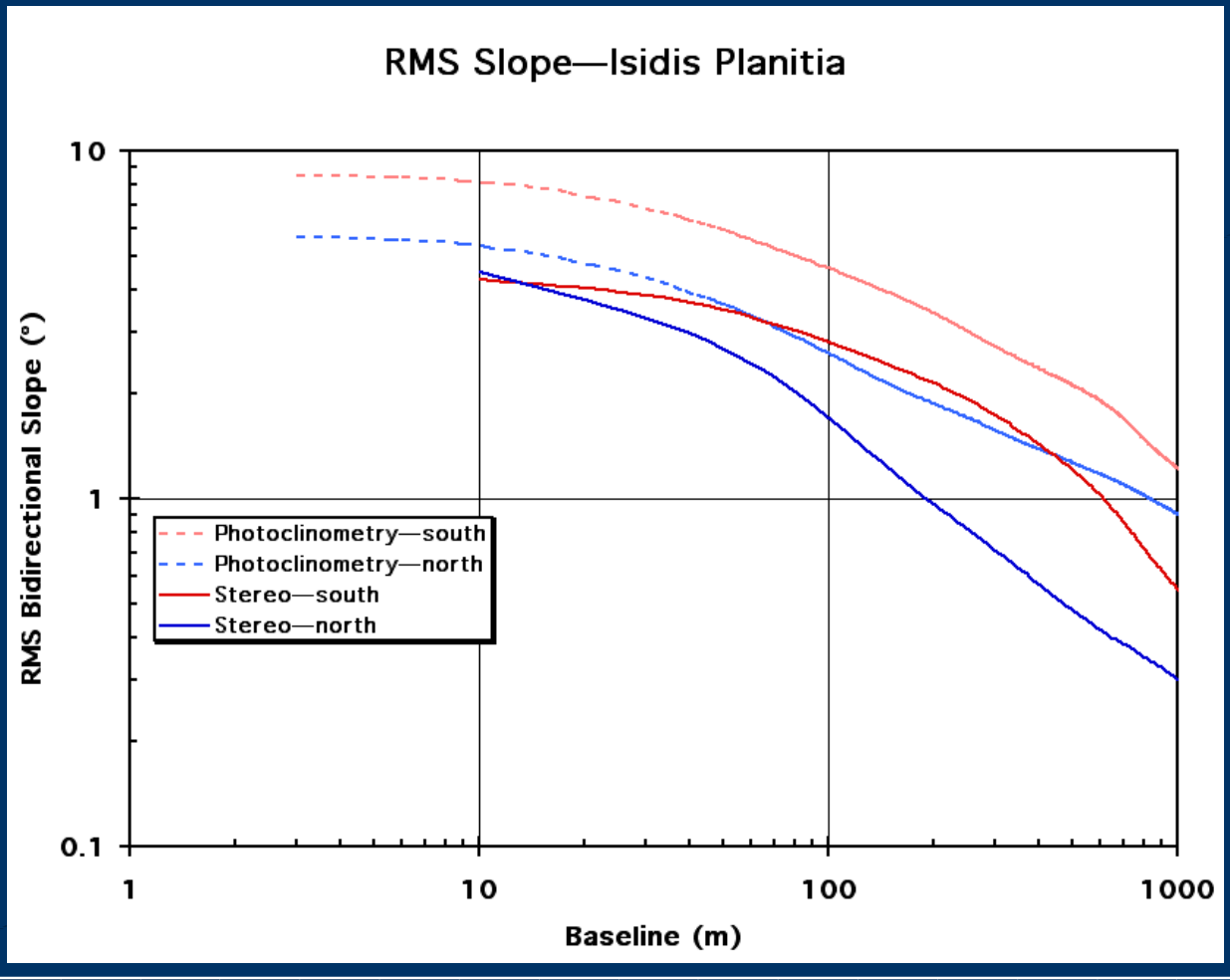
Photoclinometry resolves dunes, gives best slope estimates

# Gusev: Slope vs. Baseline



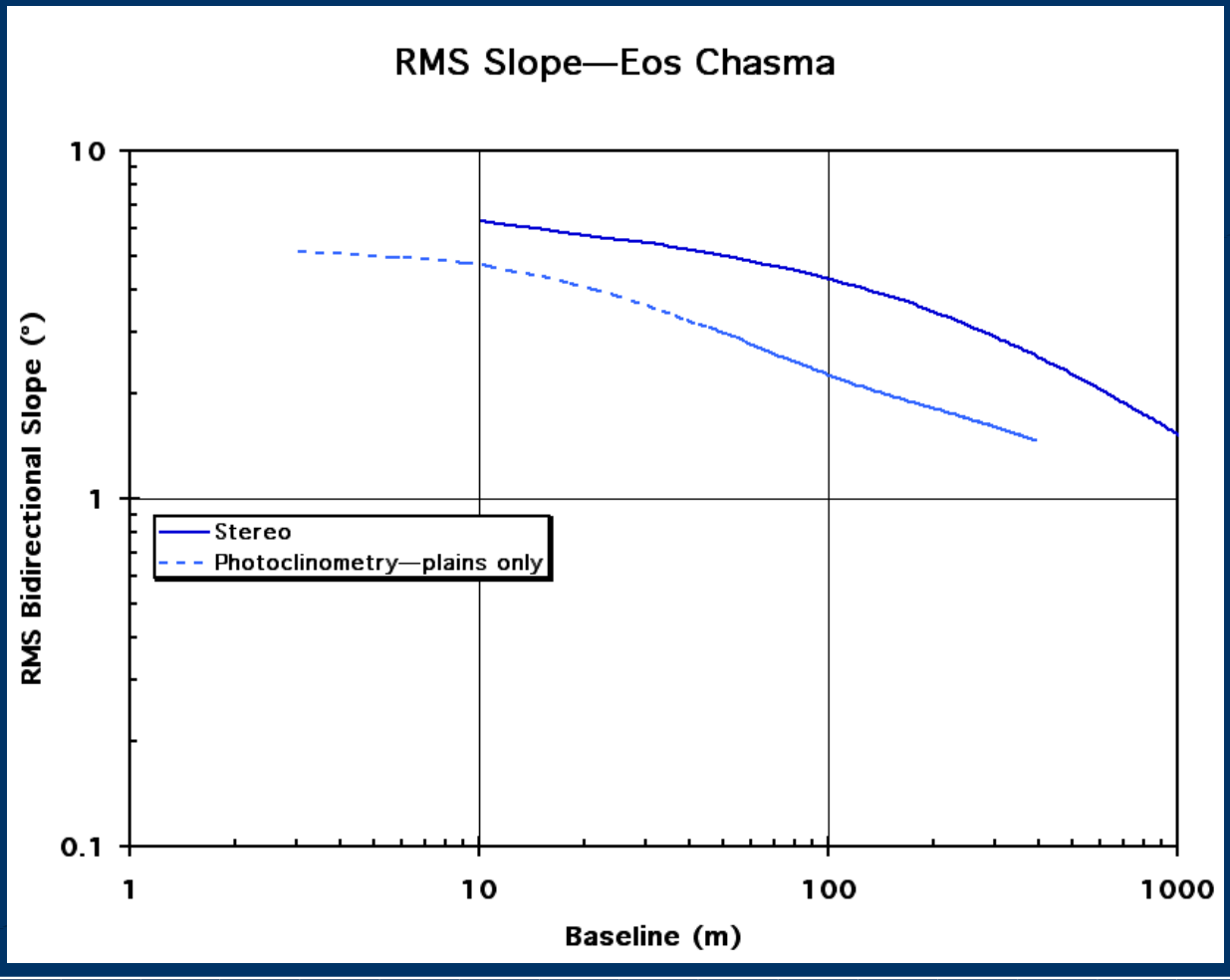

- Stereo partly resolves main roughness elements
- Photoclinometry resolves these features better
- Long-base slope estimates are compatible, so photoclinometry results preferred
- "Outside crater" is more typical

# Isidis: Slope vs. Baseline




- Stereo, photoclinometry both resolve roughness elements
- Photoclinometry slopes too high (albedo-related artifacts, sampling effect)
- Stereo results preferred

# Eos: Slope vs. Baseline




- Stereo resolves main roughness elements
- Photoclinometry confirms no un-resolved features
- Photoclinometry slopes less due to area sampled (away from major ridge)
- Stereo results preferred

# Summary of Statistics

| Site | How | Base | RMS Bdir | 99% Adir | 99% @ 5 m |
|---|---|---|---|---|---|
| Melas | St | 10 m | 2.4° | 12.6° | 12.6° |
| Melas | PC | 3 m | 13.2° | 41.4° | 38.2° |
| Gusev-crater | St | 10 m | 2.8° | 16.3° | 17.5° |
| Gusev-crater | PC | 3 m | 4.2° | 15.3° | 15.0° |
| Gusev | St | 10 m | 5.6° | 24.9° | 26.6° |
| Gusev | PC | 3 m | 9.4° | 32.3° | 32.0° |
| Isidis-N | St | 10 m | 4.7° | 25.6° | 27.0° |
| Isidis-N | PC | 3 m | 5.7° | 22.3° | 21.9° |
| Isidis-S | St | 10 m | 4.1° | 20.1° | 22.0° |
| Isidis-S | PC | 3 m | 8.5° | 31.2° | 30.8° |
| Eos | St | 10 m | 6.3° | 34.4° | 37.6° |
| Eos | PC | 3 m | 5.8° | 23.5° | 23.0° |

# Challenges #6 and #7

- Complete characterization of sites
  - Stereoanalysis of additional sites (and other samples of these sites) as more MOC stereopairs are acquired
  - Develop control to remove undulations
  - Photoclinometry without use of stereo DEM to constrain amplitude (haze estimates)
- Develop rationale for site selection if all sites are too rough for engineering safety criterion